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## An Ergonomic Analysis of Ingredient Batching in a Dairy Bottling Facility

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# **An Ergonomic Analysis of Ingredient Batching in a Dairy Bottling Facility**

By Laila Elhidmi and Hayden Johnson  
Presented to Dr. Abulhassan

Murray State University Spring 2020



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# Introduction

**Dairy production facilities rely on batching operators to unload palletized ingredients and mix them into products that meet consumer specifications**

**Work-related musculoskeletal disorders (WMSDs) and injuries reported in the past five years:**

**One case of shoulder impingement syndrome**

**One case of carpal tunnel syndrome (CTS)**

**Two cases of trigger finger**

**Three low back strains**

**Six other cases of strains (wrist, elbow, shoulder)**

**Frequent complaints of low-back pain, and concerns of ergonomic risk**

**Characterize the ergonomic risk factors associated with commonly performed batching processes and evaluate possible solutions**

# A Brief Review of Relevant Literature

**According to an “Ergonomic Evaluations of Packaging Worker’s Posture in a Manufacturing Company”**

**78% of employees abducted their upper arms**

**18% were raising their shoulders**

**7/10 indicated a high rating risk of upper body parts (neck, shoulder and wrist)**

**Another study, “Association between postures and work-related musculoskeletal discomforts (WRMD) among beverage bottling workers” found,**

**Palletizing and depalletizing workers complained of pain or discomfort where the shoulders were raised and abducted >45 degree to reach overhead in order to remove or put back bags on the upper layers of the pallet or conveyor**

**Depalletizing workers that reported discomfort = 52.2% neck, 73.5% shoulders, 38.1% wrist, and 61.1% lower back**

**Palletizing workers that reported discomfort = 64.3% neck, 77.4% shoulders, 41.7% wrist, and 64.3% lower back**



# Methods

**Five subjects were observed performing daily job tasks in producing eight batches over a 12-hour shift**

**Age:**

**Mean = 46.78 years (SD = 14.18 years)**

**Sex :**

**80% males, 20% females**

**Weight:**

**Mean = 202.33 (SD = 25.94)**

**Height:**

**Mean = 70" (SD = 2.12")**

**BMI:**

**Mean = 29.11 (SD = 4.27)**

**Equipment**

**Rapid Upper Limb Assessment (RULA), 3DSSPP Biomechanical Modeling, Lifting Fatigue Failure Tool (LiFFT), Bluebeam Revu 2019, tape measure, video recording equipment**





# Analysis

**Ergonomic analysis was performed remotely via collected photographs, video recordings, and measurements of the workspace**

# Rapid Upper Limb Assessment (RULA)

Multiple RULAs all resulted in score of 7 which indicates high ergonomic risk associated with routine postures

This task requires further investigation and the implementation of changes

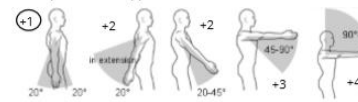


ERGONOMICS  
P.L.U.S.

RULA Employee Assessment Worksheet

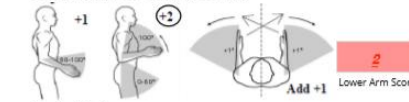
## A. Arm and Wrist Analysis

### Step 1: Locate Upper Arm Position:



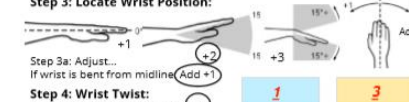
Step 1a: Adjust...  
If shoulder is raised: +1  
If upper arm is abducted: +1  
If arm is supported or person is leaning: -1

### Step 2: Locate Lower Arm Position:



Step 2a: Adjust...  
If either arm is working across midline or out to side of body: Add +1

### Step 3: Locate Wrist Position:



### Step 4: Wrist Twist:

If wrist is twisted in mid-range: +1  
If wrist is at or near end of range: +2

### Step 5: Look-up Posture Score in Table A:

Using values from steps 1-4 above, locate score in Table A

### Step 6: Add Muscle Use Score

If posture mainly static (i.e. held >10 minutes): +0  
Or if action repeated occurs 4X per minute: +1

### Step 7: Add Force/Load Score

If load < 4.4 lbs. (intermittent): +0  
If load 4.4 to 22 lbs. (intermittent): +1  
If load 4.4 to 22 lbs. (static or repeated): +2  
If more than 22 lbs. or repeated or shocks: +3

### Step 8: Find Row in Table C

Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

Wrist and Arm Score

Wrist Score

Wrist and Arm Score

Wrist and Arm Score

Wrist and Arm Score

Wrist and Arm Score

Wrist and Arm Score

## Scores

Table A		Wrist Score			
Upper Arm	Lower Arm	Wrist Twist	Wrist Twist	Wrist Twist	Wrist Twist
1	1	1	2	2	3
2	2	2	2	2	3
3	3	3	3	3	4
4	4	4	4	4	5
5	5	5	5	5	6
6	6	6	6	6	7

Upper Arm	Lower Arm	Wrist Twist	Wrist Twist	Wrist Twist	Wrist Twist
1	1	1	2	2	3
2	2	2	2	2	3
3	3	3	3	3	4
4	4	4	4	4	5
5	5	5	5	5	6
6	6	6	6	6	7

Upper Arm	Lower Arm	Wrist Twist	Wrist Twist	Wrist Twist	Wrist Twist
1	1	1	2	2	3
2	2	2	2	2	3
3	3	3	3	3	4
4	4	4	4	4	5
5	5	5	5	5	6
6	6	6	6	6	7

Upper Arm	Lower Arm	Wrist Twist	Wrist Twist	Wrist Twist	Wrist Twist
1	1	1	2	2	3
2	2	2	2	2	3
3	3	3	3	3	4
4	4	4	4	4	5
5	5	5	5	5	6
6	6	6	6	6	7

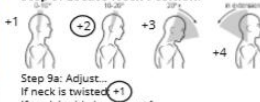
Upper Arm	Lower Arm	Wrist Twist	Wrist Twist	Wrist Twist	Wrist Twist
1	1	1	2	2	3
2	2	2	2	2	3
3	3	3	3	3	4
4	4	4	4	4	5
5	5	5	5	5	6
6	6	6	6	6	7

Upper Arm	Lower Arm	Wrist Twist	Wrist Twist	Wrist Twist	Wrist Twist
1	1	1	2	2	3
2	2	2	2	2	3
3	3	3	3	3	4
4	4	4	4	4	5
5	5	5	5	5	6
6	6	6	6	6	7

Upper Arm	Lower Arm	Wrist Twist	Wrist Twist	Wrist Twist	Wrist Twist
1	1	1	2	2	3
2	2	2	2	2	3
3	3	3	3	3	4
4	4	4	4	4	5
5	5	5	5	5	6
6	6	6	6	6	7

## B. Neck, Trunk and Leg Analysis

### Step 9: Locate Neck Position:



Step 9a: Adjust...  
If neck is twisted: +1  
If neck is side bending: +1

### Step 10: Locate Trunk Position:



Step 10a: Adjust...  
If trunk is twisted: +1  
If trunk is side bending: +1

### Step 11: Legs:

If legs and feet are supported: +1  
If not: +2

### Step 12: Look-up Posture Score in Table B:

Using values from steps 9-11 above, locate score in Table B

### Step 13: Add Muscle Use Score

If posture mainly static (i.e. held >10 minutes): +0  
Or if action repeated occurs 4X per minute: +1

### Step 14: Add Force/Load Score

If load < 4.4 lbs. (intermittent): +0  
If load 4.4 to 22 lbs. (intermittent): +1  
If load 4.4 to 22 lbs. (static or repeated): +2  
If more than 22 lbs. or repeated or shocks: +3

### Step 15: Find Column in Table C

Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in Table C.

Neck, Trunk, Leg Score

Neck, Trunk, Leg Score

Neck, Trunk, Leg Score

Neck, Trunk, Leg Score

Neck, Trunk, Leg Score

Neck, Trunk, Leg Score

Neck, Trunk, Leg Score

Neck, Trunk, Leg Score

Neck, Trunk, Leg Score

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Neck, Trunk, Leg Score

Neck, Trunk, Leg Score

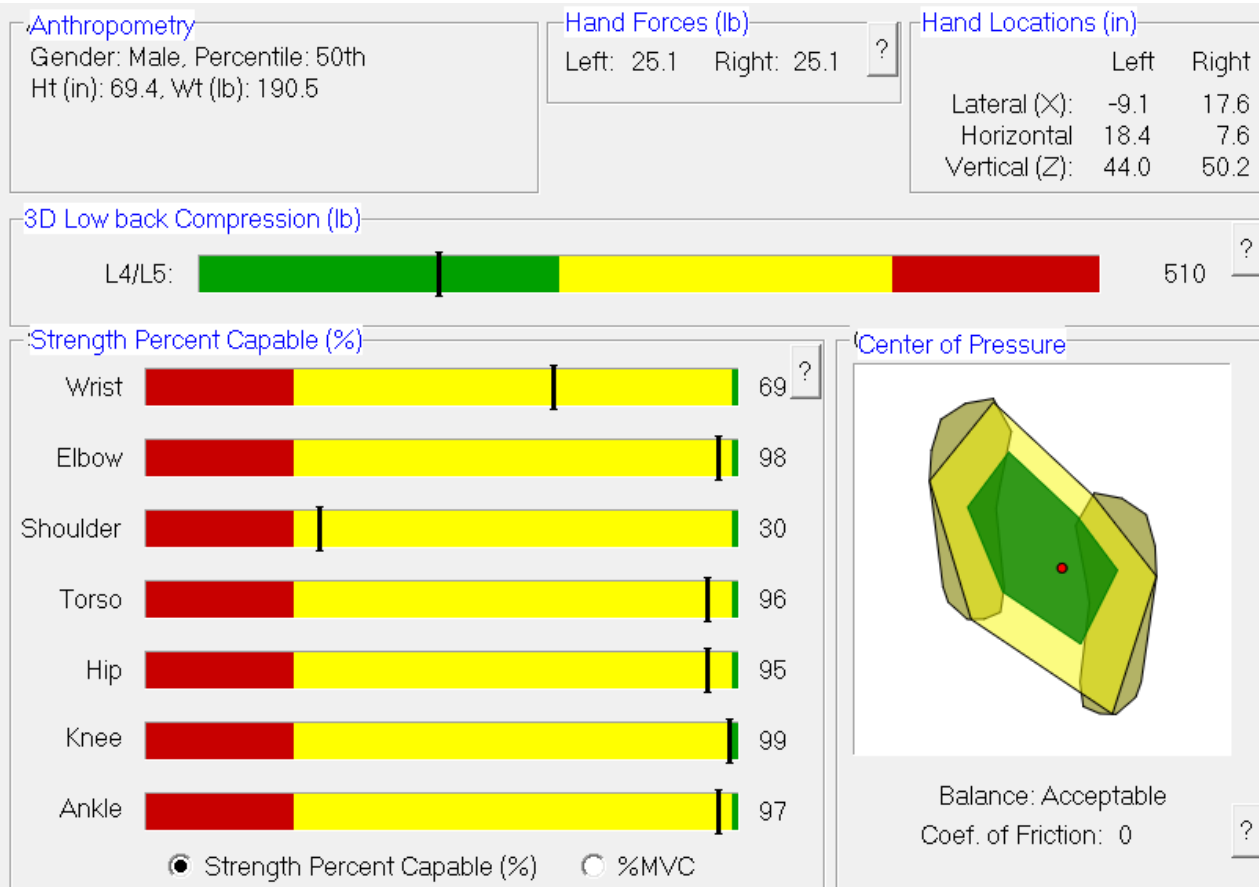
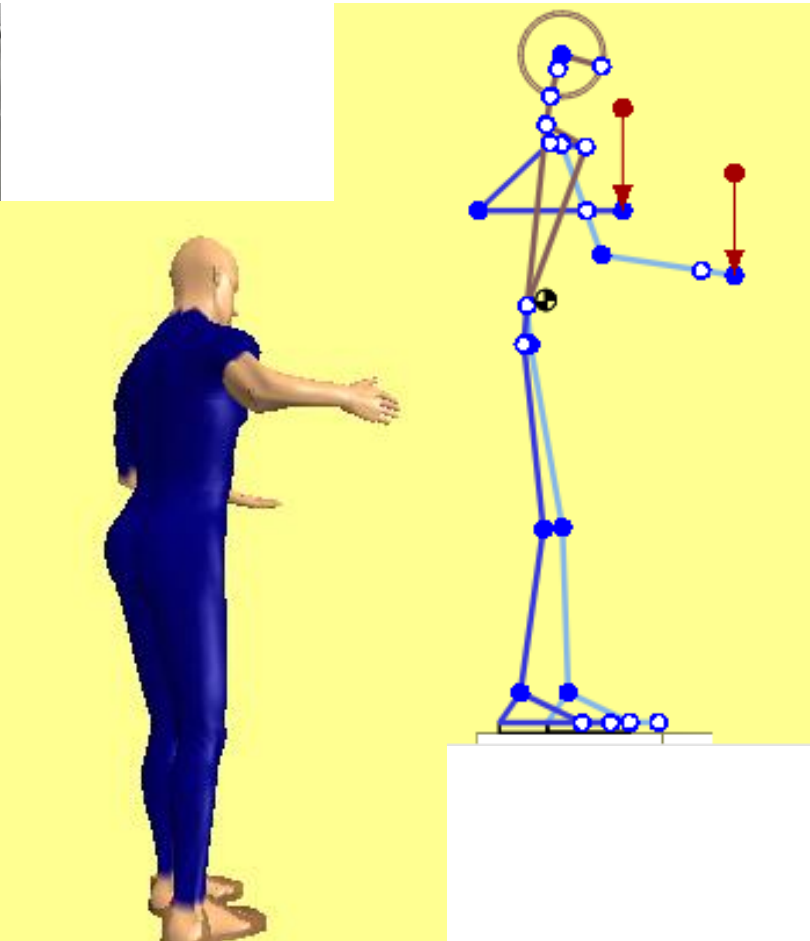
Neck, Trunk, Leg Score





# 3DSSPP Biomechanical Modeling

The model below estimates a compressive force of 510 lbs. in the L4/L5 disc and that 30% of 50th percentile males would have enough strength to exert the required load for five seconds with at least two minutes of rest



# Lifting Fatigue Failure Tool (LiFFT)

According to this ergonomic evaluation tool, the combination of these tasks and estimated cumulative damage which may result is considered low-moderate, with a 30% probability of this job being high risk

The Lifting Fatigue Failure Tool

Unit: [English](#) | Metric

Task #	Lever Arm (inch)	Load (lb)	Moment (ft.lb)	Repetitions (per work day)	Damage (cumulative)	% Total (damage)
1	14.41	56.21	67.5	24	0.0011	35.5
2	11.893333	56.21	55.7	14	0.0004	12.9
3	13.695	50.4	57.5	9	0.0003	9.7
4	15.025	56.65	70.9	3	0.0002	6.5
5	13.57	50.4	57.0	4	0.0001	3.2
6	15.485	56.65	73.1	3	0.0002	6.5
7	28.35	43	101.6	2	0.0005	16.1
8	29.66	36	89.0	1	0.0001	3.2
9	12.53	8.6	9.0	12	0.0	0.0
10	28.76	36	86.3	2	0.0002	6.5
Total Cumulative Damage:					0.0031	
Probability of High Risk Job * (%):					30.0	

[Reset](#)

[Calculate](#)

\* A "High Risk Job" is defined as a job experiencing 12+ injuries per 200,000 hours worked, as defined by Marras et al. (1993).

Marras, W.S., Lavender, S.A., Leurgans, S.E., Rajulu, S.L., Allread, W.G., Fathallah, F.A., Ferguson, S.A. (1993). The role of dynamic three-dimensional trunk motion in occupationally-related low back disorders: The effects of workplace factors, trunk position, and trunk motion characteristics on risk of injury. *Spine* 18(5): 617-628.

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Please cite this paper to support the authors:

[Gallagher, S., Sesek, R. F., Schall, M. C., & Huangfu, R. \(2017\).](#)

[Development and validation of an easy-to-use risk assessment tool for cumulative low back loading: The Lifting Fatigue Failure Tool \(LiFFT\).](#)  
[Applied Ergonomics](#), 63, 142-150.



# Results

**Current work practices in batching operations could significantly increase the risk of developing WMSDs**

## **Materials handled:**

**Bagged ingredients weighing  
45 – 56 lbs.**

## **Repetitions:**

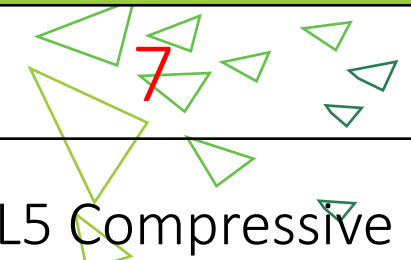
**Mean = 11.38 lifts/ingredient  
(SD = 14.00)**

## **Frequency:**

**Mean = 5.134 lifts/min (SD = 4.41)**

## **Current controls:**

**Pallet leveler, task rotations,  
stretching regiment**

Tools	Result
RULA	
3DSSPP (for 50 <sup>th</sup> percentile male population)	L4/L5 Compressive Forces: Mean = 569.8 (SD = 92.608)  Percentage of the population capable: Mean = 44.2 (SD = 26.95)
LiFFT	Probability of High-Risk Job: 26.06% (SD = 6.46)

# Suggestions for Improvement

**While batching operators are currently provided a pallet leveler, some pallets still exceed 72" in height at its lowest setting, above what is generally considered to be an acceptable starting height for lifts**

**If the current pallet leveler were lowered and a spring table lift/pallet carousel were mounted on top, this would provide additional adjustability along with the capability to rotate and bring the ingredients closer to the operator, eliminating the need for the operator to reach over the pallet to pull bags closer to them before lifting**

**Based on ingredient data collected, 50 lb. bags of compressed chocolate powder with a slick coating required 37.5% less force to pull compared to 50 lb. bags of loosely packed chocolate powder with a textured surface.**







# Conclusions

**RULAs performed suggest that batching operators may be exposed to high levels of ergonomic risk, while the 3DSSPP and LiFFT assessments indicated low-moderate levels of risk**

**Previous injuries and MSDs have increased workers' discomfort and likely impacted job performance**

**Our suggestions will assist in eliminating the stress of repetitive lifting, bending, twisting, and reaching forward, in addition to maintaining the standard working height as the ingredients are unloaded from the pallets**

**Follow-up surveillance should be performed on-site after the implementation of the suggested improvements**

Fructose 3001775 5169 Lbs 5169  
Sweet Whey Powder 3001732 1793 Lbs 1793  
Skim Powder RFree 994 lbs 994  
Sucrose 3001780 -Non GMO 7915 lbs 7915

CORN SYRUP 25 DE 3002030 2498 Lbs 2498

Stabilizer, Danisco IcePr GS 373 00 749 448 Lbs 448

Org Vit A Sens Effects 695873 3001832 415 Gram 10616228 91571

Vanilla, Virginia Dare 1001054058 103

**Thank You**  
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	Gallons	Lbs	Bf%	Msnt%	11%	15%	Density	Lbs of BFat	Lbs of Skim
Targets	7500	68850	5.11	10.01	5.11	31.29	9.18	3518.4	49198.6
Calculated	0.00	68850.9	5.11	9.86	5.51	31.18			



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